Individual Analysis II: Uncertainty Analysis for Testing

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Introduction

The team is partnered with Red Feather to create a heating solution for the homes on the Native American reservation. The Native American reservation used to receive coal to heat their homes, but the coal plant has recently been shut down leaving them looking for another affordable heating solution. In addition, coal can cause respiratory problems. The team is building a solar furnace to sustain renewable energy for the homes. The solar furnace scaled down prototype heat output must be calculated to produce 1500 Watts. This will be conducted using an Arduino UNO with Arduino IDE software. The uncertainty analysis for the Arduino is conducted to account for various errors. In addition, a new linear interpolation was found from probability and statistical analysis.

Calculations

The Arduino Uno is programmed to read voltage temperature and change the value into a temperature reading. The equation used in combining multiple errors in testing is shown below. This is important for finding the total error in uncertainty. [1]

$$dz = \sqrt{\frac{\partial F}{\partial X_1}^2 dx_1^2 + \frac{\partial F}{\partial X_2}^2 dx_2^2 + \cdots \frac{\partial F}{\partial X_n}^2 dx_n^2} \quad \text{[eqn. 1]}$$

X=influence coefficient

dx=error in influence coefficient

dz=total error uncertainty

The influence coefficients are factors that influence the total measurement. Standard error is used to measure accuracy from a sample population by using standard deviation. The standard error was found in excel by using the standard deviation of the voltage measurements multiplied by a 95% confidence interval for 10 voltage values. The error due to the accuracy for the temperature sensor is 0.01 volts. This is shown in the variable b_p which is the error from instrumentation. This was then put into the formula above to find an overall uncertainty of 0.09 volts. The overall uncertainty is important so the team knows how true the value is compared to the actual value.

Table 1: Uncertainty Analysis

v	10
s_{yx}	0.0541
$t_{(10,95)}$	1.812
s_p	0.0981
b_p	0.01
u_p	0.098

$$s_{yx}[standard\ deviation] = \sqrt{\frac{\sum(voltage - average\ voltage)^{\wedge}2}{number\ of\ data\ points}} \quad \text{[eqn.2]}$$

$t_{(10,95)} = 95\%\ confidence\ interval\ with\ 10\ data\ points$

$s_p = standard\ error$

$b_p = error\ from\ instrumentation$

$u_p = total\ uncertainty$

In addition, the original calibration for the Arduino was fluctuating so a new calibration curve was found using probability and statistics in excel. The original calibration calculated used the equation shown below by using a linear interpolation from a graph from Arduino in Appendix 1.

$$temperature[C°] = voltage[v] * 100 - 50 \quad \text{[eqn. 3]}$$

The following table shows the intermediate calculations to find the new calibration shown in equation 4.

Table 2: New Calibration Calculations using Probability and Statistics

voltage average[v]	0.678
variance	0.03
temperature average[C]	14.96
covariance	2.74
b1	5.88
b0	15.66

$b1 = slope\ of\ new\ calibration$

$b0 = y - intercept\ for\ new\ calibration$

The new calibration result is important because it will produce a better reading for the temperature values for the solar furnace. This will allow the team to get as close to the actual temperature as possible. The new equation for calibration is shown below.

$$temperature[C°] = 5.89 * voltage[v] + 11.85 \quad \text{[eqn. 4]}$$

The variance is the average of the voltage subtracted from the voltage average and then squared. The variance equation is shown below. [2]

$$variance = \frac{\sum(voltage - average\ voltage)^2}{number\ of\ data\ points} \quad \text{[eqn. 5]}$$

The covariance equation is shown below. The covariance is meant to show the correlation between data points. [2]

$$covariance = \frac{\sum(voltage - average\ voltage) * (temperature - average\ temperature)}{number\ of\ data\ points} \quad \text{[eqn. 6]}$$

The b1 equation is shown below. This is used to find the slope of the new calibration. [3]

$$b1 = \frac{covariance}{variance} \quad \text{[eqn. 7]}$$

The b0 equation is shown below. This is used to find the y-intercept for the new calibration. [3]

$$b0 = average\ temperature - b1 * average\ voltage \quad \text{[eqn. 8]}$$

Conclusion

In conclusion, the uncertainty of the voltage for the Arduino is 0.09 volts. The new calibration equation found from probability and statistics is shown in equation 3. The temperature reading is used in the heat output equation. This is important in finding the heat output of the solar furnace to satisfy the engineering requirement of producing 1500 Watts with the scaled down prototype. In addition, the uncertainty of the voltage is important to understand how much the Arduino temperature is off from the actual value.

References

[1]*Error Analysis (Uncertainty Analysis) Experimental Projects Lab 1* [PDF]. (n.d.). Cambridge: MIT.

[2] Montgomery, D. C., & Runger, G. C. (2019). *Applied statistics and probability for engineers*. Milton, Qld: Wiley.

[3] Cordi, M. (Director). (2019, May 21). *How to calibrate a TMP36GZ temperature sensor* [Video file]. Retrieved October 5, 2020, from https://www.youtube.com/watch?v=e2TVIf1CLPI&t=541s

[4] *Low Voltage Temperature Sensors* [PDF]. (2015). Arduino. Retrieved October 5, 2020, from https://www.analog.com/media/en/technical-documentation/data-sheets/TMP35_36_37.pdf

Appendix 1

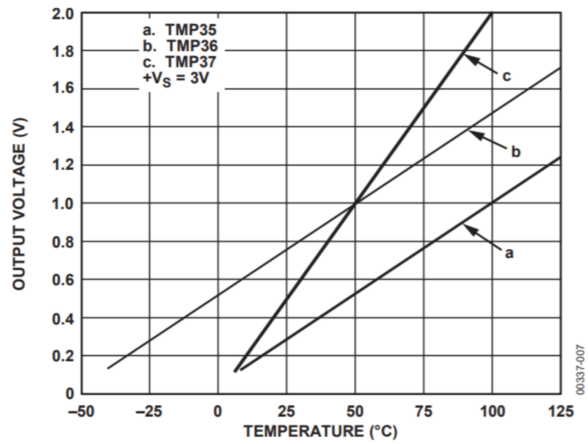

Figure A1: Output Voltage vs Temperature from Arduino Data [4]